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TERRESTRIAL MAGNETISM.—*The magnetic and electric survey of the earth: Its physical and cosmical bearings and development.*[1] J. A. FLEMING, Department of Terrestrial Magnetism, Carnegie Institution of Washington.

The last presidential address[2] covered so thoroughly and admirably the progress during the past quarter-century of research respecting the earth's magnetic field that I fear the presentation of my subject-matter may impose some repetition upon you. My excuse, however, is that you have brought it upon yourselves since apparently the accepted rule is that presidential addresses should cover efforts or developments in the particular science in which the speaker is engaged and, therefore, presumably competent to speak.

In terrestrial magnetism and electricity, as in most physical sciences, coordinated data and experiment must pave the way for the development and test of theory. The problems presented are extremely complex and so interrelated with other physical, geophysical, and cosmical ones that they offer greatest resistance to attack; their solutions, therefore, call in marked and exceptional degree for cooperative endeavor of the highest and most unselfish caliber. Herein appears to lie the most promising hope of ultimate successful interpretation, in part or in whole, of the many fascinating complexities and variations shown by these fields of the earth and its atmosphere.

In the collection of data through the magnetic and electric survey of the earth attention must be given to the geographical and space distributions and the time variability characterizing the phenomena

[1] Address of retiring President of the Philosophical Society of Washington, January 9, 1926.

[2] D. L. HAZARD, This JOURNAL 15: 111–125, 1925.

concerned. The word "survey" is here used in a broad sense to include not only isolated land and sea observations to determine the geographic distribution and long-period variations but also continuous work at fixed observatories to follow the time variations and coordinated effort in the physical laboratory, in the astronomical and astrophysical observatory, and in the instrument shop.

The survey, so far as the earth's magnetic field is concerned, may be said to have had its inception in the work of Halley on the *Paramour Pink* during 1698 to 1701 "on an expedition to improve the longitude and variations of the compass" in the north and south Atlantic oceans under the auspices of the British Government. To its leader we owe the method of portraying by isomagnetic curves the distribution of the magnetic elements although he used it only for declination. At present the magnetic survey involves the measurement of the direction and intensity of the lines of magnetic force, that is, of the so-called magnetic elements on the earth's surface, namely, declination, inclination, and horizontal intensity. Defining the magnetic meridian at any place as the direction of the compass needle there, the declination is the angle between the magnetic meridian and the astronomic meridian, the inclination (or dip) is the angle which a magnetic needle mounted on a horizontal axis and swinging in the vertical plane containing the magnetic meridian makes with the horizontal plane, and the horizontal intensity is the horizontal component of the total intensity of the earth's field. Charts showing curves drawn through places of equal values of the magnetic elements are called isogonic, isoclinic, and isodynamic charts, respectively..

Our planet is not uniformly magnetized, and its magnetic poles are distant 1,200 miles and more from its geographic poles, with the north pole approximately in latitude 70° north and in longitude 96° west of Greenwich, and the south pole approximately in latitude 73° south and in longitude 156° east of Greenwich; the line joining these poles passes some 750 miles away from the center of the earth. In addition, there are many regions where local natural disturbances, for example, those caused by magnetic ore deposits, give rise to further irregularities in the earth's general field. Therefore, observations of the magnetic elements must be made at many places to delineate the field with reasonable correctness.

There are also progressive changes in the earth's magnetic elements, which vary from place to place and for the same place from time to time. Since no laws satisfactorily covering these phenomena have been found,

secular-variation observations, as they are called, must be made at widely scattered points and at frequent intervals of time so that the isomagnetic charts can be corrected for such progressive changes.

The complexity of the earth's magnetism is still further increased by other periodic and irregular changes. Thus there is a daily variation of each element, the range of which varies with time, geographic position, season, and sunspot frequency and other cosmical relations. There is also an annual inequality. Perhaps the most fascinating of the magnetic perturbations are those irregular ones known as magnetic storms. These are of various types. Some occur almost simultaneously over the whole globe, their intensity more frequently increasing as the station is nearer a magnetic pole. Others having more local characteristics occur, for example, on the daylight face of the earth. Types of disturbances are (1) those designated "pulsations" of a ripple-like or pulsatory character, (2) those called "sudden commencements" of sharp and sudden beginning without any marked preliminary indication in the record, and (3) others best defined by their designation as "bays" of less irregular character lasting about 30 minutes or less. Some have the feature of repetition at the same place and time of day over periods of three to five days and even more as though there were local clouds of ionized material rotating with the earth influenced by cosmic radiations on successive days until the clouds are dissipated; this type, when aurorae are visible as at high-latitude stations, exhibits parallel features of recurrence, a phenomenon beautifully shown in Mawson's recently published discussion[3] of the records of the aurora polaris made by the Australasian Antarctic Expedition. Magnetic storms are generally simultaneous with displays of polar lights, are related in some measure to the sun's condition increasing with increased solar activity, and are frequently accompanied by pronounced disturbances of the natural electric currents within the earth.

The data for the preparation of isomagnetic and isoelectric charts for a given epoch are obtained by observations at many "distribution" stations and by repeat determinations made from time to time at selected "secular-variation" stations. Those for the study and investigation of the short and complex periodic, progressive, and irregular inequalities of the earth's magnetism and electricity are obtained best from continuous observations extending over many years at fixed observatory stations. At present there are about 50 active magnetic observatories, of which less than 20 per cent carry on electric work.

[3] Scientific Reports, Ser. B., 2: Pt. 1, 1925.

Their geographic distribution is by no means ideal, fully 40 per cent being in Europe and only about 20 per cent in the southern hemisphere.

Natural electric currents or "earth-currents," originally noted by Barlow, circulate in the crust of the earth and are generally weak, but in times of disturbance may attain such strength as to interfere seriously with telegraphic transmission. These currents and the electric phenomenon of atmospheric electricity including polar lights may be grouped as the electric field of the earth and its atmosphere. The survey, so far as this field is concerned, may be said to have had its initiation with Franklin's classical kite experiments on the electrification of clouds and the nature of lightning and with the nearly contemporaneous work of Le Monnier which showed that even under cloud-free conditions the atmosphere is the seat of an appreciable electric field. The development of the study of the electric phenomena of the atmosphere advanced somewhat after the introduction of the quadrant electrometer by Kelvin and following the work of Exner. Greater study and development began after the introduction by J. J. Thomson of the ionic theory of the electrical conduction in gases, and under the enthusiastic leadership of Elster and Geitel the foundations were laid for present-day investigations of the electric field. These investigations have assumed, in the last decade, a greater importance because of their bearings on recent theories of electricity and because of their intimate association and correlations with the phenomena of the earth's magnetism with which strong parallelism as regards space and time distribution and variations is found. The range and perturbations of the electric diurnal-variations are very much greater than those for the magnetic elements and are much more dependent upon meteorological conditions, but on the other hand the change of absolute values with geographic position is not so great.

In general, the atmospheric-electric phenomena observed include potential gradient, conductivity, and ionization. On clear days the earth is negatively charged with respect to the air, and in the lower layers of the atmosphere the potential difference between the earth and a point in the atmosphere increases with its height above the earth. The change in potential per meter is defined as the potential gradient; under good meteorological conditions its average value determined at many stations on land and sea is of the order of 125 volts per meter at sea-level, that is to say, the potential of the air 1 meter above the ground is 125 volts higher than the potential of the ground. Fair-weather values of the negative and positive conductivities of the lower

atmosphere are of the order of 10^{-4} E.S.U., the positive conductivity being in general 10 to 20 per cent larger than the negative conductivity. Observations of ionic content indicate average values ranging from 500 to 1,000 ions of either sign per cubic centimeter, the number of positive ions being about 20 per cent greater, thus leaving a volume charge in the atmosphere amounting to several hundred free positive ions per cubic centimeter. Values of the air-earth current-density from simultaneous observations of potential gradent and conductivity are of the order of 10^{-6} E.S.U., the value being somewhat greater over land than over sea.

The contributon to the survey through continuous work at fixed observatories was initiated by Gauss in the establishment in 1832 of a magnetic observatory at Göttingen to measure variations of declination and horizontal intensity. Following this, with the assistance of Weber and Humboldt, Gauss aroused such interest that international cooperation for the extension of the survey to regions unexplored magnetically was effected soon after 1840 in the establishment of a number of observatories in widely separated parts of the world and in the development of satisfactory instruments for determining all three magnetic elements and their variations. The history of the development of observatory methods, instruments, and progress is of great interest but must be passed over to permit some account of the survey and of results obtained in the last two decades, of their physical and cosmical bearings, and of the future needs.

The contribution to the magnetic and electric survey to which I wish to refer more in detail is that[4] in which I have had the privilege for the past 20 years to work with Bauer, Peters, Ault, Fisk, Mauchly, and others in the Department of Terrestrial Magnetism of the Carnegie Institution of Washington and which has been an effective agency for coordination and cooperation. While a large share of the general survey has been taken by that Department, very notable contributions have been made by various countries either through repetition of former magnetic surveys or through new surveys. Our work has been confined mainly to the oceans and to those countries or regions where magnetic data were generally lacking. In some regions the magnetic surveys required were accomplished by cooperation with existing organizations or with interested individual investigators. Furthermore, particular effort has been made to use every opportun-

[4] C. I. W. Year Books, 4–24: 1905–1925. C. I. W. Pub. No. 175, 1–5: 1912, 1915, 1917, 1921, 1926.

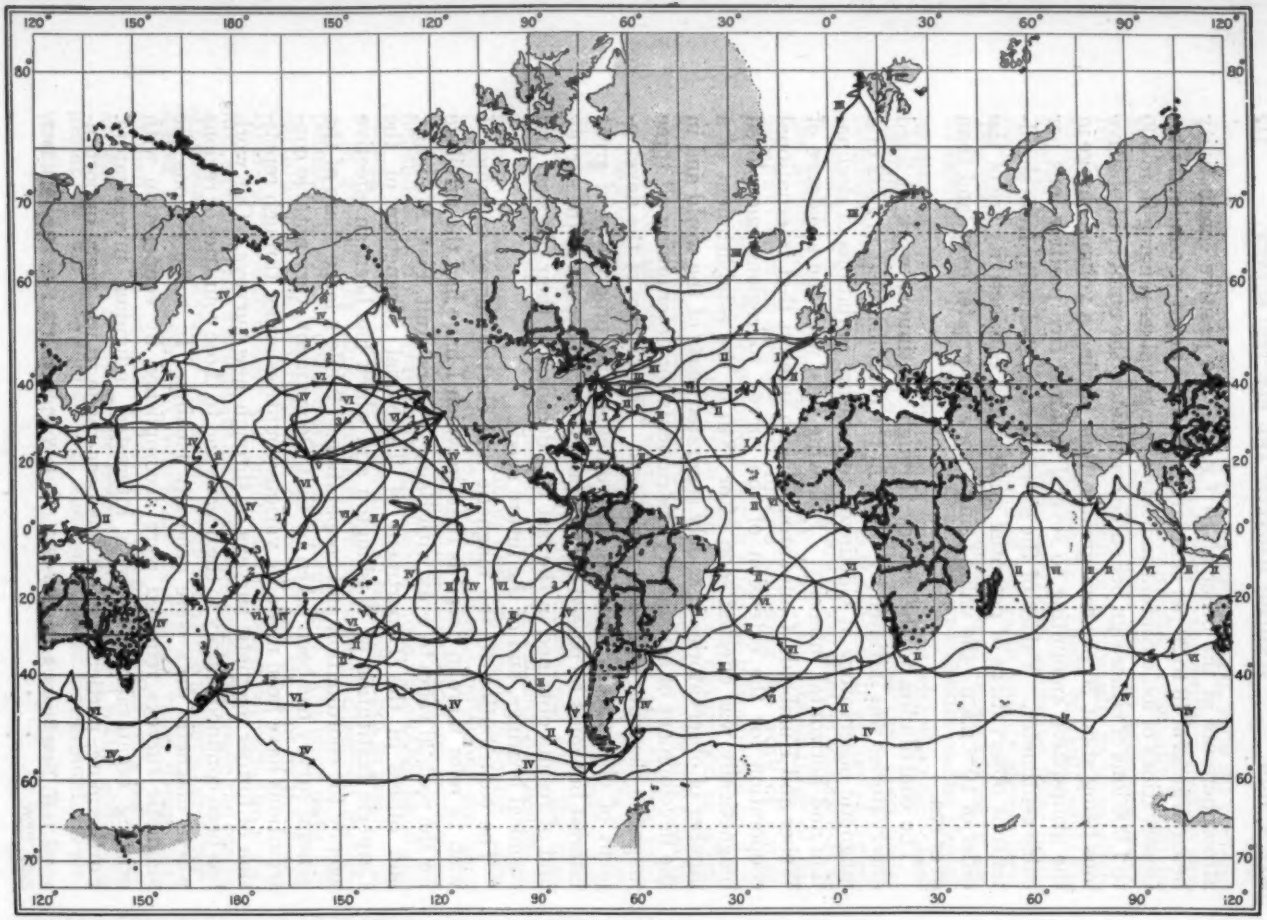


Fig. 1.—Magnetic Survey Work of the Carnegie Institution of Washington during 1905–1925. (Cruises of the *Galilee* are indicated by Arabic numbers, those of the *Carnegie* by Roman numerals. Black dots show the land stations.)

ity to cooperate with expeditions[5] to the polar regions where data are very scarce. Such work was done on the Peary Arctic Expedition, the Australasian Antarctic Expedition under the leadership of Mawson, the *Maud* expeditions of Amundsen in the Arctic Sea during 1918 to 1921 and 1922 to 1925, and the Baffin Land and North Greenland expeditions under the command of MacMillan during 1921 to 1922 and 1923 to 1924.

To determine with requisite completeness the so-called Gaussian coefficients defining at any one epoch the earth's general magnetic field for investigating the theory and origin of the earth's magnetism, accurate values of the magnetic elements are needed at fundamental points which may be about 5° apart in latitude and longitude or about one station for each 100,000 square miles. On land, because of the frequent local and regional disturbances often caused by geological formations, the endeavor has been to attain distribution of primary stations on the average of one about every 5,000 square miles. For regions of local disturbance, observations are generally made at subordinate stations near the primary ones, but at sea, because of the usual absence of local disturbance, except in shallow waters or near land masses, stations may be much farther apart than on land. The land work (see Fig. 1) has been carried on, to greater or lesser extent according to circumstances, in every major political subdivision of Africa except British and Italian Somaliland; in every country in Asia excepting Afghanistan, the Himalayan States, and Chosen, but including every province of China except Tibet; in every state of Australia; in New Zealand; in 11 European countries; in every country of North America; in Greenland and Iceland and the ice of the Arctic Sea; in every country of South America; in the principal islands of the Atlantic and Indian oceans; and in 25 of the principal groups and isolated islands of the Pacific Ocean. During 1905 to 1925, inclusive, nearly 5,000 stations were established. In the last five years many of the stations have been reoccupied, so that at the present time from 60 to 70 per cent of the work done each year consists of such reoccupations which now number nearly 700 (see Fig. 2). Table 1 summarizes the land stations geographically, showing also the distribution of secular-variation primary stations.

Now that the greater part of the necessary distribution of magnetic stations has been realized, increasing attention is being given to obtain-

[5] C. I. W. Pub. No. 175, **1**: 115–116, 1912. C. I. W. Pub. No. 175, **2**: 127, 1915. Terr. Mag., **27**: 36–56, 1922. C. I. W. Year Book, **21**: 278, 1922; **24**: 188, 194, 1925. C. I. W. Pub. No. 175, **5**: 191, 1926.

Fig. 1.—Magnetic Survey Work of the Carnegie Institution of Washington during 1905–1925. (Cruises of the *Carnegie* are indicated by Roman numerals. Black dots show the land stations.)

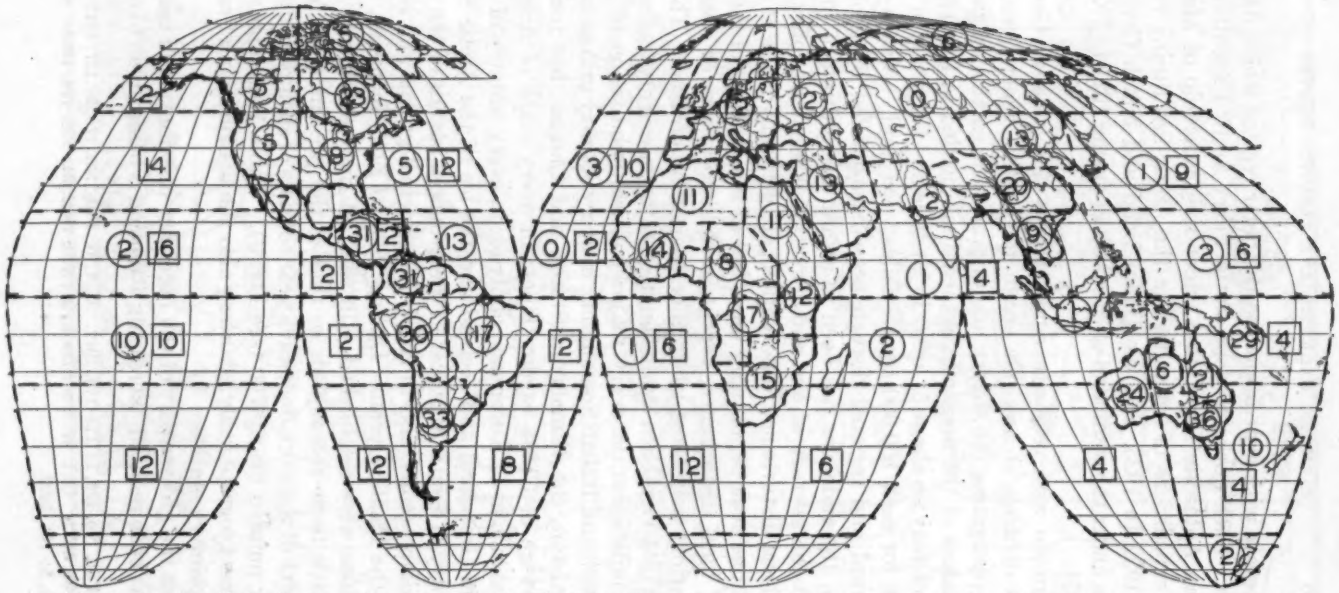


Fig. 2.—Regional Distribution of Magnetic Secular-Variation Data through December 31, 1925, obtained by the Carnegie Institution of Washington. (Numbers in circles apply for land work and in squares for sea work. Base-map is that of J. Paul Goode, copyright by the University of Chicago Press.)

ing secular-variation data. Particular attention has also been given the selection of primary secular-variation stations so that together with existing observatories they may form a net with approximately 500-mile intervals. Since 1922 the diurnal variations in the three magnetic elements on some one day for each have been determined at every reoccupation, using the combined C. I. W. magnetometer-

TABLE 1.—GEOGRAPHIC DISTRIBUTION OF MAGNETIC WORK ON LAND BY THE CARNEGIE INSTITUTION OF WASHINGTON DURING 1905–1925

GEOGRAPHICAL DIVISIONS	STATION OCCUPATIONS			REPEAT LOCALITIES
	Primary	Auxiliary	Secondary	
Africa	1053	56	13	88
Asia	755	63	39	64
Australasia	612	57	78	96
Europe	94	31	9	14
North America	586	122	31	77
South America	815	111	31	111
Islands:				
Atlantic	154	115	47	30
Indian	94	16	9	4
Pacific	188	48	25	44
Mediterranean	8	0	0	3
Antarctic	25	1	5	2
Arctic Sea	26	67	212	1
Totals	4410	687	499	534

inductor. These data will be used in the determination of correction-factors to reduce to mean of day with the aid of data at observatories more or less distant from the field stations. Such a net-system of stations has been planned for Mexico, Central America, and South America, and observations have been made accordingly. Similar nets have been begun in Australia and Africa and at scattered points elsewhere. The results so far amply justify the plan, though there is room for improvement which ultimately must come with the development of instruments better adapted to this particular form of land work. The need is to secure secular-variation data at intervals of five years and even at shorter intervals in those regions where the changes are unusually rapid. To insure continuance of a series it is planned to observe always at one or two stations comparatively close to the primary secular-variation stations, thereby making it possible to transfer the series in case the station originally selected becomes unsuited.

The ocean work[6] of the Department was initiated in 1905. The early work in the Pacific Ocean during 1905 to 1908 was carried out on the chartered brigantine *Galilee*. In 1909 a specially designed non-magnetic vessel, the *Carnegie*, was built, and all our work at sea since that time has been done with this vessel excepting a special expedition into Hudson Bay in 1919 on a chartered schooner. The summary of ocean magnetic work of the *Galilee* and the *Carnegie* during 1905 to 1921 as given in Table 2 (see also Fig. 1) shows the total number of

TABLE 2.—SUMMARY OF MAGNETIC WORK AT SEA BY THE GALILEE AND THE CARNEGIE DURING EIGHT CRUISES IN 1905–1921

OCEAN AND APPROXIMATE EPOCHS OF OBSERVATION	NUMBER OF NAUTICAL MILES	NUMBER OF OBSERVED VALUES		CRUISE INTERSECTIONS USED FOR ANNUAL-CHANGE DATA	SQUARE STATUTE MILES PER STATION	
		Declination	Inclination and horizontal intensity		Declination	Inclination and horizontal intensity
Pacific: 1905–08, 1912, 1915–16, 1921	181,423	1,800	1,183	47	35,600	53,700
Atlantic: North, 1909–10, 1913–14, 1919; South, 1910–13, 1920	92,053	1,039	682	27	30,300	46,300
Indian: 1911, 1920	43,060	477	282	7	59,100	99,800
Total	316,536	3,316	2,147	81	37,300	57,500

observed values of declination to be over 3,300, and of inclination and horizontal intensity to be over 2,100, the stations being distributed in the Pacific, Atlantic, and Indian oceans in the proportion of about 4, 2, and 1, respectively. The average time-intervals and the average distances apart for stations for the *Galilee* work have been decreased by about 40 per cent in the *Carnegie* work because of the increased efficiency resulting from the fact that the *Carnegie* was built for the work and because of the steady improvement in the instrumental appliances and observational methods. While the oceans have now been quite thoroughly traversed between parallels 60° north and 60° south, there still remain areas of 500,000 square miles or more in extent, especially in the Pacific Ocean, within which no magnetic observations have been made. However, the area in general for each declination station is less than half the theoretical requirement of 100,000 square miles, and for an inclination and intensity station about three-fifths of the theoretical requirement. Thus it may be said that there are

[6] C. I. W. Year Book, **4**: 264–274, 1905. C. I. W. Pub. No. 175, **3**, **5**: 1917, 1926.

available accurate ocean magnetic data at points distributed about 3° in latitude and 3° in longitude or, on the average, about 200 miles apart.

The results of the ocean work have been incorporated in the isomagnetic charts of the leading hydrographic offices, and chart-errors, which reached an appreciable magnitude in 1905, are now within limits sufficient for all economic purposes and to a large degree for general magnetic investigations. Such as do exist may usually be attributed to imperfect knowledge of the secular changes which are more complicated even over the deep sea than was supposed to be the case.

TABLE 3.—ATMOSPHERIC-ELECTRIC STATIONS AT SEA AND DIURNAL-VARIATION SERIES DURING CRUISES OF THE CARNEGIE, 1915–1921, FOR ONE OR MORE ELEMENTS AND SERIES OF FOUR HOURS OR MORE

CRUISE	OCEAN							
	Atlantic		Pacific		Indian		Southern	
	Number of stations	Number of D.V. series	Number of stations	Number of D.V. series	Number of stations	Number of D.V. series	Number of stations	Number of D.V. series
IV	22	1	293	27			76	14
V	38	2	66	7				
VI	164	8	178	27	118	10		
Totals....	224	11	537	61	118	10	76	14

Total for all oceans 1915–1921: stations, 955; diurnal-variation series, 96.

During the earlier work of the *Carnegie* atmospheric-electric observations were made at sea primarily to develop methods and appliances for the determination of electric distribution. Much of this preliminary work gave relative values only, but as the result of this work and of experimental work in the laboratory it was possible, beginning in March 1915 with the fourth cruise of the vessel, to make systematic absolute determinations of the atmospheric-electric elements at sea.

The atmospheric-electric results[7] at sea from 1915 to 1921 include potential gradient (see Fig. 3), negative and positive ionic content, conductivity, and ionic mobility, penetrating radiation, radioactive content, together with accompanying detailed meteorological data. They are summarized in Table 3 for 955 stations in all oceans at which one or more elements were observed and for 96 series for diurnal-

[7] C. I. W. Pub. No. 175, **3**: 361–422, 1917; **5**: 385–424, 1926.

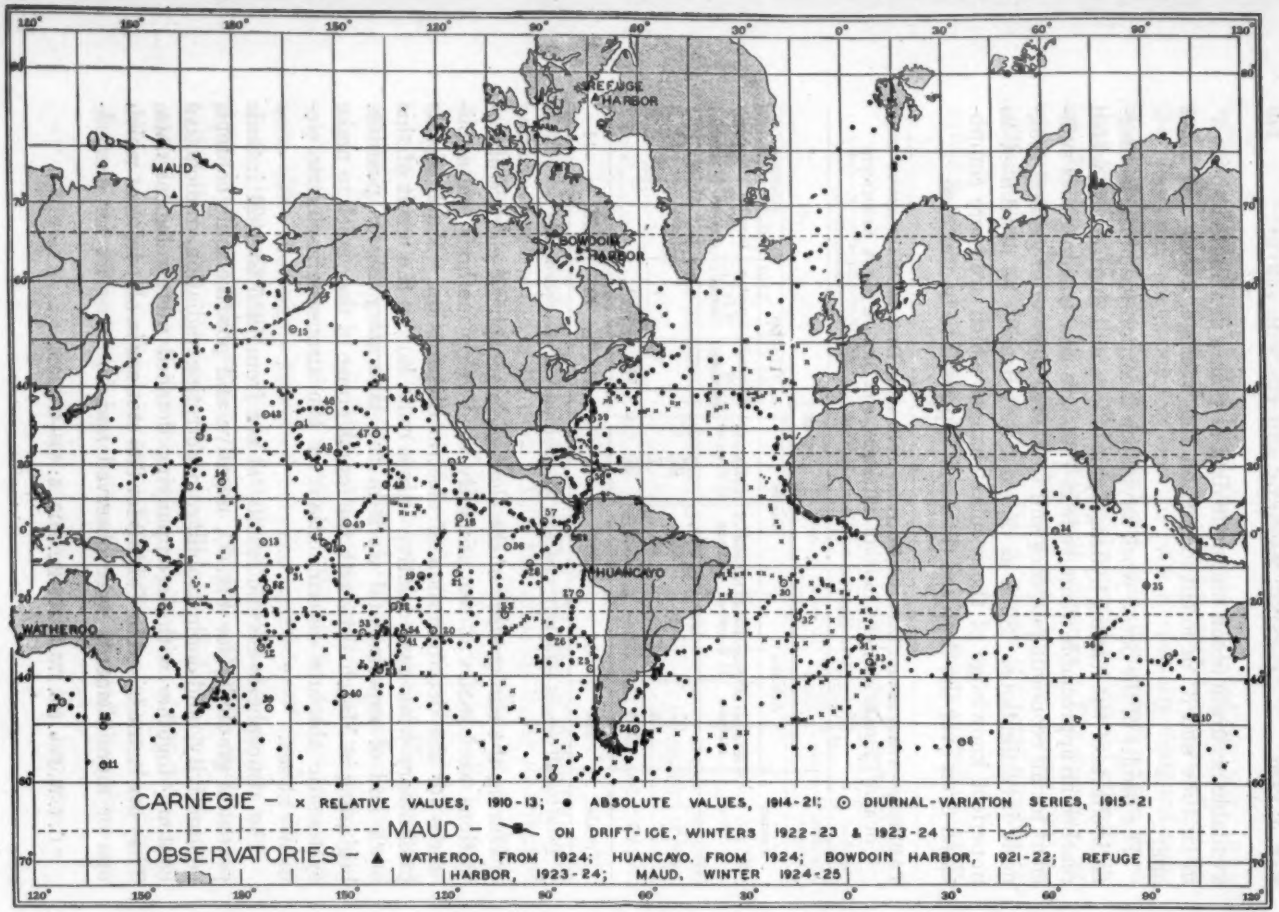

REFUGE HARBOR
MAUD
BOWDOIN HARBOR
HUANCAYO
WATHEROO
CARNEGIE – × RELATIVE VALUES, 1910-13; • ABSOLUTE VALUES, 1914-21; ⊙ DIURNAL-VARIATION SERIES, 1915-21
MAUD – ON DRIFT-ICE, WINTERS 1922-23 & 1923-24
OBSERVATORIES – ▲ WATHEROO, FROM 1924; HUANCAYO, FROM 1924; BOWDOIN HARBOR, 1921-22; REFUGE HARBOR, 1923-24; MAUD, WINTER 1924-25

Fig. 3.—Electric Survey Work of the Carnegie Institution of Washington during 1910–1925. (Distribution of atmospheric potential-gradient stations of the *Carnegie*, of the *Maud*, and at observatories.)

variation of one or more elements including four hours or more of observation.

The question of standards to coordinate the work by various organizations the world over and in the development and design of instrumental appliances, especially for the high order of precision attained in the magnetic observations, has been important. There being no agreement among nations as to international magnetic standards, it was necessary that the Department of Terrestrial Magnetism adopt standards in 1905 at the very beginning of its work.[8] Control of the instrumental constants has been carefully maintained, and the precision of the provisionally adopted standards to the order of 0′.2 in declination and inclination and of one five-thousandth part in horizontal intensity has been confirmed by frequent and detailed intercomparisons (1) with field and observatory instruments of various types at the Standardizing Magnetic Observatory in Washington, (2) at over 80 per cent of the active magnetic observatories of the world repeated at intervals of from three to five years at the leading observatories, and (3) with absolute electric instruments especially designed for the determination of the magnetic intensity and inclination. The standard in horizontal intensity is justified within the limit of reasonable precision by the results, direct and indirect, of comparisons with electromagnetic instruments summarized in Table 4. Of this type of instrument three have been designed and constructed within recent years,[9] namely, the Barnett sine-galvanometer of the Carnegie Institution of Washington, the Schuster-Smith magnetometer of the National Physical Laboratory at Teddington, and the Watanabe electric magnetometer of the Japanese Central Bureau of Weights and Measures; the constants for all three instruments are based on absolute electrical units.

These investigations of magnetic standards have stimulated great interest and have been supported by most generous cooperation in time and laborious observation by practically every organization engaged in the world survey. The importance of the subject has been recognized in recent resolutions[10] and recommendations on governmental and international control of standards by such bodies as the International Geodetic and Geophysical Union in 1924 at Madrid and

[8] C. I. W. Pub. No. 175, **2**: 211–278, 1915; **4**: 395–475, 1921.

[9] C. I. W. Pub. No. 175, **4**: 273–294, 1921. Proc. Phys. Soc., **26**: 279–291, 1914. Proc. Phys.-Math. Soc. Japan, Ser. 3, **2**: 210–223, 1920.

[10] Trans. Sec. Terr. Mag. Elect., Madrid, 1924. K. Ned. Met. Inst., No. 112, 1924.

gradient stations of the *Carnegie*, of the *Maud*, and at observatories.)

the International Meteorological Conference of Directors and the International Meteorological Committee in 1923 at Utrecht.

TABLE 4.—SUMMARY OF RESULTS OF HORIZONTAL-INTENSITY COMPARISONS BETWEEN PROVISIONAL INTERNATIONAL MAGNETIC STANDARD OF CARNEGIE INSTITUTION OF WASHINGTON AND ELECTRIC MAGNETOMETERS, AUGUST, 1922, TO MARCH, 1923*

STANDARD OR INSTRUMENT		HORIZONTAL-INTENSITY CORRECTION, $\frac{\Delta H}{H}$, ON			
Description	Designation	IMS	SG	SS	W
Provisional International Magnetic Standard of Carnegie Institution of Washington†	IMS		+0.00007	+0.00015‡	+0.00031
Sine galvanometer No. 1 of Carnegie Institution of Washington	SG	−0.00007		+0.00008‡	+0.00024
Schuster-Smith magnetometer of National Physical Laboratory	SS	−0.00015‡	−0.00008‡		+0.00016
Watanabe electric magnetometer No. 1	W	−0.00031	−0.00024	−0.00016‡	

* The table is to be read thus, for example first row: SG − IMS = + 0.00007H; SS − IMS = +0.00015H; W − IMS = +0.00031H. The results are based for the three electric instruments on absolute units.

† This provisional standard was adopted in 1914 (see *Res. Dep. Terr. Mag.*, Vol. II, 1915, pp. 270–279).

‡ This value is subject to correction for any station-difference which may be found between the two observing piers used at Teddington, England, for the comparisons in September 1922.

Continued extensive field use of the C. I. W. magnetometer-inductor[11] for the determination of declination and horizontal intensity by magnetic methods and of the inclination by the inductor method shows this type of instrument to be very satisfactory even under most severe conditions. The time required for complete determinations of the three magnetic elements using the magnetometer-inductor is greater than would be required by an instrument based entirely on electromagnetic methods, but the difficulties of maintaining electric batteries and appurtenances on long journeys under severe and variable field conditions would offset any gain by such an instrument since the actual time required for magnetic observations is but a small part of that required for all the work at a field station. In view, however, of the desirability of portable designs of electromagnetic instruments for observatory and special field use, for example, diurnal-variation work at land stations and on board ship at sea, an electric magnetometer and

[11] Terr. Mag., 18: 105–110, 1923.

variometers with rotating coils are being designed for the observation of declination and, by suitably mounting the coil on a horizontal axle permitting orientation of its rotation axis at any angle, of the intensity-components, and inclination.

The Carnegie Institution of Washington following its policy, not to duplicate the work of other organizations but to obtain data where most needed for world-wide considerations and development, has in operation two magnetic and electric observatories in the southern hemisphere, where the distribution of existing observatories is most inadequate. One at an elevation of about 800 feet, is near Watheroo, Western Australia, about 125 miles north of Perth, and the second at an elevation of 11,000 feet above sea-level, is near Huancayo, Peru, practically on the magnetic equator and some 120 miles east of Lima. Both these observatories maintain the full program of observational and investigational work in terrestrial magnetism, atmospheric electricity, and earth-currents. The Institution is cooperating also with the New Zealand Government in the maintenance of the atmospheric-electric program at the Apia Observatory which, because of its location in the midst of the Pacific, is a unit of large importance in the magnetic and electric survey. The great altitude above sea-level of the station at Huancayo and its location, practically on the magnetic equator, with the possibility of auxiliary stations within 100 miles at differences of elevation of as much as two miles, affords unique opportunity at least for initial work in the study of altitude effects on the magnetic and electric fields. Time at all three observatories is determined by means of radio signals, thus insuring the accurate time control necessary to the study of the propagation of magnetic disturbances.

Now that the distribution stage of the general magnetic and electric survey of the earth is practically completed, we must look forward to the future needs of this survey, for as Humboldt says, "the interpretation of an undertaking of such cosmical importance depends on its long continued repetition." But first it is necessary to consider in how far we must call further upon cooperation from the physical laboratory, the astrophysical observatory, and related geophysical observations for help in interpreting the results and discussions so far made, for quoting Burgess[12] in his presidential address to this Society, "A scientific man would hardly be so rash as to pose as a prophet, yet he may, nevertheless, try to assemble and pass in review some of

[12] This JOURNAL 9: 57, 1919.

the tendencies of the time; and it is only by an intelligent examination of the underlying changes which are being produced in science and in its relation to society that he is enabled to see his way ahead a little more clearly into the mist of the future; and he may thereby be enabled, at least in some small degree, to chart his course and take advantage of the various currents that have been set in motion."

Among some results thus far obtained as a result of the magnetic and electric survey may be mentioned the following: The analysis[13] of the earth's magnetic field for the epoch 1922 for the first time based upon thoroughly homogeneous data between the parallels of 60° north and south as discussed by Bauer and his co-workers, which shows that about 95 per cent of the earth's magnetic field is to be ascribed to internal magnetic and electric systems, about 3 per cent to external systems or systems in the atmosphere and the remainder, about 3 per cent, to a magnetic system the evoking agencies of which, for example, vertical electric currents, may pass from the atmosphere into the earth and out again. Although the last two systems contribute only about 6 per cent to the magnetic field as observed on the earth's surface, their further study may be of first importance in revealing entirely new facts in the investigation of the origin of the earth's electric field. This discussion also shows that the secular variation results from changes in both direction and intensity of magnetization with the lapse of time. The intensity apparently has steadily decreased during the past 80 years at an average annual rate of one fifteen-hundredth part, and its average value for corresponding parallels north and south is generally larger for land-predominating than for ocean-predominating parallels. There are, however, larger secular changes in the southern or ocean-predominating than in the northern or land-predominating hemisphere. The internal uniform magnetic field of the earth as deduced from this work for 1922 is 8×10^{25} C.G.S., the relation of its components parallel and perpendicular to the earth's axis of rotation being about as five to one.

Secular-variation studies over the sea[14] by Ault and Peters and over land by Fisk,[15] especially those for Latin America and adjacent waters including all of South and Central America and the Atlantic and Pacific oceans adjoining, show results singularly like long-period types of pulsation about primary and secondary foci, and perhaps not unre-

[13] Terr. Mag., **18**: 1–28, 1923.
[14] C. I. W. Pub. No. 175, **5**: 185–191, 1926; **3**: 430–435, 1917.
[15] Terr. Mag., **29**: 139–148, 1924.

lated to those amplitude pulses of regular diurnal inequality, which vary accordingly as the disturbance waxes and wanes, so strikingly brought out by Chree's discussion[16] of magnetic phenomena in the region of the south magnetic pole. The accumulated data of the ocean survey emphasize the disadvantage of attempting to control normal secular-variation by observations at isolated island stations, most of which are notoriously centers of local magnetic disturbance; thus far, intensive work by the Department on relations of secular and diurnal variations in such locally disturbed regions has been confined to that of Fisk in the Bermudas. Ault finds, from his discussion of ocean results, regions of apparent anomaly at sea which suggest the need of sounding to determine topography and effect of sea bottom since places have been noted where residuals are persistently of the same sign over limited areas.

The discussions and analyses by Bauer, Mauchly, and their colleagues of the extensive atmospheric-electric observations at sea since 1915 have yielded results and conclusions also of fundamental importance.[17] Thus Mauchly finds the chief component of the diurnal variation of the potential gradient over the oceans is a "wave" of 24-hour period occurring simultaneously in the same phase in all localities and from consideration of land series a strong probability is established that, in general, this 24-hour wave progresses also approximately according to universal time over the entire land surface of the earth. The greatest value of the gradient occurs at an average during the year of between 17^h and 19^h Greenwich mean time, which is approximately the time when the Sun is in the meridian of the north magnetic pole of the earth, a fact indicating possibly a close relationship between the magnetic and electric fields; thus far, the character of this relationship is unexplained. In cooperative work of the Department with the Arctic-Drift Expedition of Amundsen, beautiful confirmation of this fundamental deduction has resulted from series of observations during the three winters of 1922 to 1925 through the work of Sverdrup.[18] These observations were obtained during the first two winters in the drifting ice observatory off the north coast of Siberia and during the last winter at a temporary land station near Bear Island. The data obtained for density of air-earth current from simultaneous potential-gradient and conductivity results at sea show also that atmospheric-electric

[16] London, Proc. R. Soc., A, **104**: 165–191, 1923.
[17] C. I. W. Pub. No. 175, **3**: 361–422, 1917; **5**: 385–424, 1926.
[18] MS. Scientific work of the *Maud* Expedition, 1922–1925.

phenomena can not be wholly interpreted on the basis of local conditions, however characteristic such features may be.

Not only in this but also in the evidence of solar-activity correlations is the value of a moving observatory such as the *Carnegie* clearly shown. The studies[19] by Bauer of sunspot and annual variations of atmospheric electricity and by Mauchly in atmospheric electricity, both as based on the observations during 1915 to 1921 aboard the vessel, show beautifully the close parallelism during this period of observation in all oceans between waxing and waning in sunspot activity and atmospheric potential-gradient—a parallelism whose confirmation indeed is as evident from the sea observations as it is from observations made at fixed land observatories during the same period. The general conclusion from the investigations of Bauer, Peters, Duvall, and Ennis based on land and ocean results indicates that during the cycle 1913 to 1922 the atmospheric potential-gradient increased with increasing sunspottedness by at least 20 per cent of its mean value for the cycle between the years of minimum and maximum sunspottedness. This also applies with regard to measures of diurnal variation and of annual variation of the potential gradient. The evidence, ever growing with the accumulation of observational data, that the annual variation progresses according to the time of year rather than according to local seasons, is significant from the viewpoint of solar relationship; also the maxima of activity occur near the equinoctial months March and September and the minima of activity near the solstitial months June and December, corresponding as well to the fluctuations in the activity of earth-currents and in the frequency of the northern lights.

From the great number and distribution at sea of the atmospheric-electric data secured (as shown in Fig. 3) it is now possible to prepare, tentatively, the first isoelectric chart of the oceans which shows the potential gradient varying with latitude. The regular increase from the equator to 60° north and to 60° south again suggests world-wide predominance of the chief features of this element.

A most promising method of examining the apparent interrelations of the earth's magnetic activity represented by the magnetic storms and the solar activity represented by sunspot data extending now more then a century back, is by investigating abruptly beginning magnetic storms or "sudden commencements." Recent studies by Bauer and Peters[20] of data for the high sunspot period 1906 to 1909 and for the

[19] C. I. W. Pub. No. 175, **5**: 359–384 and 385–424, 1926.
[20] Terr. Mag., **30**: 45–68, 1925.

low sunspot period 1922 to 1925 indicate possibly an origin in low magnetic latitudes and progression to the magnetic poles with an average speed around the earth such that the uninterrupted progression of an average disturbance of this type from the magnetic equator to the pole might take about 1.8 minutes. Here we see, as in other problems of cause and effect, the necessity of the greatest precision and accuracy not only in record but in thorough analysis and discussion of the magnitude of errors of the record and particularly of the time element. These studies also show the necessity of establishing a greater number of recording stations in regions where limiting conditions of the phenomena prevail, namely, the Arctic and Antarctic—a desideratum recognized by resolutions of the International Geodetic and Geophysical Union at Madrid in October 1924. Observational data regarding such propagation have been previously discussed[21] by Bauer, Faris, Chree, Chapman, Angenheister, and Rodés, with various conclusions. We must improve the control of time as recorded on the photographic records to insure accurate timing of given features to within one-fourth minute at least and to determine in how far the feature of a sudden commencement may be identical or vary with geographic distribution. This research shows need of a more accurate and reliable method for recording vertical intensity than the present type of variometer.

Briefly, some of the future needs and lines of development for the magnetic and electric survey, therefore, include (1) continued accumulation of data on land and sea, less intensive than heretofore as regards distribution stations but more so as regards observatories, and (2) concurrent theoretical discussions, experiments, and investigations in the physical laboratory and in the astronomical observatory.

While the first general ocean survey covering so large a part of the earth's surface is largely accomplished, there is still great need for additional data for the determination and investigation of marine earth-currents, for the important question of magnetic secular-variation or progressive changes and their accelerations over ocean areas, and for the examination of regions of local magnetic disturbance. There is also great need for more data for the study of the diurnal and other variations and the distribution of the electric elements and their magnetic interrelations for which sea conditions are superior to

[21] Terr. Mag., **15**: 9–30, 93–105, 1910. Göttingen, Nachr. Ges. Wiss., Math.-Phys. Kl., 1913. London, Proc. Phys. Soc., **27**: 134–153, 1914; **30**: 205–214, 1918. Terr. Mag., **27**: 162–166, 1922; **30**: 45–68, 1925.

those on land, where topography, culture, and variable meteorological elements mask the true characteristics of the phenomena. Instrumental improvements based on electromagnetic principles should include the actual continuous or semi-continuous recording by photography of the magnetic and electric fields at sea.

The practical impossibility of realizing a network of continuous recording observatories so close together as to permit direct interpolation to correct survey data for diurnal variation makes some provision necessary for deriving diurnal variations for each of the elements at selected field stations. Comparisons of such data with records obtained simultaneously at the nearest observatory must increase our limited knowledge of the way in which the range, time of extremes, and other characteristics of the diurnal variations change from place to place and in the two hemispheres. The recent extraordinary developments in the evolution of physical science demand increased accuracy and constant functioning of observatory recording instruments. While the present declination and horizontal-intensity variometers are of high precision, the vertical-intensity variometer is not entirely satisfactory, because certain mechanical difficulties inherent in suitably supporting the moving magnetic element cause frequent discontinuities of base-line and of scale-value. An important instrumental need, therefore, is the design and construction of variation instruments on electrical principles, for example, by means of rotating coils oriented appropriately for the study of the various intensity components with recording galvanometers of sensitivity suited to various problems being studied.

Upper-air observations of the magnetic and electric elements and similar observations below the surface of the land and sea are needed because magnetic and electric activity, diurnal ranges, and other periodic and irregular variations may undergo considerable modification with changes in altitude, as is already indicated by the few data gathered in upper-air electric work. Such development calls for careful study of methods and the design of instruments most suitable for accurate determinations of changes above the surface of the earth in unmanned carriers or below the sea in bells.

The magnitude of the work of observation, control, and reduction of magnetic and electric data from continuous records at observatories is appallingly great, and most urgent needs include development of simplified methods for such reductions and for publication. There also is need of better theoretical foundations for really representative

but simple scales to characterize magnetic and electric activities upon which to build relations with physical and cosmical phenomena. To make possible the complete mathematical analyses of the magnetic and electric fields, it is very desirable that additional observatories be established and distribution stations be occupied in regions where auroral displays are frequent and where limiting conditions of the other phenomena prevail. In the regions above latitude 60° north and 50° south, that is, over 18 per cent of the earth's surface, there are very few data. Therefore, every advantage must be taken of every opportunity to cooperate with, and to encourage such work by, polar expeditions.

The world-wide increasing interest in the magnetic and electric survey has been such within the past few years that many countries heretofore inactive in such work have taken it up intensively both at field stations and at observatories. Through the rapid development and design of special instruments and standardized equipment, it is now possible to obtain physical coordination of new work being undertaken. Cooperative efforts with physical laboratories and astronomical observatories are evolving and offer much promise. Thus a research between the Geophysical Laboratory and the Department of Terrestrial Magnetism on the effect of pressure on the critical temperature of magnetization for pure metals and natural ores is in progress, and may yield results not only applicable in the investigation of the contribution of magnetized materials in the earth's crust to the permanent magnetic field but also to physics, to geology, and to applied geology in the detection of ore deposits. Cooperative work[22] has recently been carried on by the Department with the Bureau of Standards, the Naval Research Laboratory, and various other organizations interested in questions concerned with upper-air conductivity particularly with the supposed Kennelly-Heaviside layer. Breit and Tuve, through theoretical and experimental attack evolved from an idea originally suggested by Swann, have recently shown the existence of such a layer at a height averaging about 150 kilometers above the earth's surface. Such a layer affords a possible explanation of some variations in the earth's magnetic field according to which the motions of the layer induce electric currents which in turn may produce some of the variable part of the earth's magnetism, an idea advanced by Stewart, further developed by Schuster, and quantitatively considered by Chapman; the motion of the layer as a whole may affect the electrical con-

[22] C. I. W. Year Book, **24**: 1925.

dition of the lower atmosphere and produce changes in the observed atmospheric potential-gradient. Here again we have the possibility of an intimate relation in that the ionized gases of such a layer may consist largely of helium, and its further study may lead to better understanding of northern lights following the recent laboratory experiments[23] of Vegard at Leyden and of McLennan and Shrum at Toronto.

Another development of the survey calling for experimental work in the laboratory is a proposed study of earth-currents at sea suggested by Mauchly and Gish. The extent and homogeneity of the oceans of our globe, as compared with land areas, are such that the ocean area must be given, as we have seen from the magnetic and atmospheric-electric results at sea, a large measure of consideration in the collection of any geophysical data that assume an approach to completeness. The homogeneity acts in a number of ways to make the sea especially favorable for the observations of earth-currents as compared with any of the available solid portion of the earth's crust.

The "penetrating radiation" or high frequency rays of cosmic origin, recently reported upon by Millikan[24] and also earlier investigated by Kohlhörster[25] and others, must have some bearing particularly on the electric field of the earth. These results stimulate further experimental investigation in the laboratory to give more definite information about the properties of penetrating radiation and its possible relation to the maintenance of the earth's charge; for example, investigations on the nature of the scattering of hard gamma-rays from various materials.

As regards the relations between atmospheric electricity and radio phenomena, Dellinger[26] has summarized specific interrelations to include (1) lightning and thunder-clouds and atmospheric disturbances, (2) variations of atmospheric potential-gradient and conductivity and similar variations of atmospheric disturbances in field intensities, and (3) earth's magnetic field and upper-air conductivity and differing radio-wave propagation at various frequencies.

Among the problems of the electric field demanding further consideration, as stated in the 1924 report[27] of the committee on observational

[23] Comm. Phys. Lab. Univ. Leyden No. 175, 1925. London, Proc. R. Soc., A, 108: 501–512, 1925.

[24] Science, 62: 445–448, 1925. Nature, 116: 823–825, 1925.

[25] Die durchdringende Strahlung in der Atmosphäre, Hamburg, 1924.

[26] Bull. Nation. Res. Council, No. 53: 61–62, 1925.

[27] Trans. Sec. Terr. Mag. Elect., Madrid, 1924.

work in atmospheric electricity of the International Geodetic and Geophysical Union, are: (1) Character of the annual variation of potential gradient over the southern hemisphere as to whether as a whole its maximum is in the summer or in the winter and further observations confirming the universal-time function of the daily variation of potential gradient, a matter of fundamental importance, both calling for more measurements especially at sea; (2) more measurements for determining air-earth currents, if possible, by direct measurement of the electricity passing from a portion of the earth's surface into the atmosphere during the whole year taking into account current due to precipitation, these to be made at a number of widely-distributed stations, thus affording some means of determining the total loss of electricity from the earth's surface; and (3) additional measurements on the conductivity of the air and its variations and their changes with geographic position. Other problems which lend themselves better to investigation at individual stations involve the part played by different factors in ionizing the air, the electricity of thunder-storms and the distribution of electrical factors in the upper air. The development of instruments for air-earth currents and conductivity is still in the experimental stage.

The importance of cooperative work in the study of interrelation of solar activity and the magnetic and electric activities of the earth has been emphasized further by consideration of international bodies including the International Geodetic and Geophysical Union[27] in 1924 and the International Research Council for the study of solar and terrestrial relationships in July 1925,[28] the latter calling particular attention to the necessity of organizing a service for the supply of information to solar observatories as to magnetic storms, prospective or in progress.

A possible extension of the survey is indicated in Chevallier's recent and interesting paper[29] discussing the direction of magnetization of various lava flows at Mount Etna. Following lines indicated by Folgheraiter, Brunhes, and others in studies of the magnetism of rocks and lavas and with a knowledge of the dates of eruption he has deduced declination secular-variation curves. Perhaps by the cautious use of such methods we may delve into the history of the earth's magnetism before the period of observation and even perhaps in geologic ages.

In a summary of some of the interrelations of the magnetic and elec-

[28] Trans. Internat. Astron. Union, 2: 186–188, 1925.
[29] Ann. Phys., Paris, 4: 5–162, 1925.

tric survey with other branches of physical, geophysical, and cosmical work we may include: In oceanography and navigation—the study of local magnetic disturbances along coast lines, on islands and at sea as related to depths, bottom formations and earth-currents; in geology, geodesy and seismology—relations to magnetic and electric susceptibilities and character of materials in the crust of the earth, to gravity anomalies and to isostacy; in engineering and physics—relations to radio and telegraphic transmission, applications of magnetic and electric methods to mineral surveys and determinations, fundamental problems of magnetism, electricity and radiation; in meteorology and astronomy—relations to meteorological conditions including upper-air conditions, dust content and absorption and scattering of sun's radiation, to solar activity especially for measures other than visual, to penetrating radiation, to planetary motions, and to magnetic and electric conditions of heavenly bodies. All of these demand continued and incessant prosecution of the survey by observations at temporary stations and at fixed and floating observatories on the surface of the earth, in the upper regions of the atmosphere and in ocean depths, and in the physical laboratory and the astronomical observatory if we are to make nearer approach to the elucidation of the phenomena concerned. The continued cooperative efforts of international and national bodies and organizations and of physicists, geophysicists, astronomers, and astrophysicists must be looked forward to and counted upon in an ever-increasing degree in the future development and interpretation of the magnetic and electric survey of the earth.

PALEONTOLOGY.—*New Eocene mollusks from Jackson, Miss.*[1] WYTHE COOKE, U. S. Geological Survey.

For many years the writer has been accumulating data for a monographic account of the stratigraphy and paleontology of the formations of Jackson age in the United States, and from time to time he has published short papers dealing with the stratigraphy or correlation of some of those deposits.[2] As the completion of this report has been unavoidably delayed, it seems advisable to publish now some of the new species which were to have been described in it.

[1] Published by permission of the Director of the U. S. Geological Survey.

[2] The age of the Ocala limestone: U. S. Geol. Survey Prof. Paper **95**: 107–117. 1915.
The stratigraphic position and faunal associates of the orbitoid foraminifera of the genus Orthophragmina from Georgia and Florida: U. S. Geol. Survey Prof. Paper **108**: 109–113. 1917.

All of the shells figured in this paper are in the U. S. National Museum. They were collected by Dr. T. Wayland Vaughan and the writer from the Jackson formation (upper Eocene) at the stations listed below. With the single exception of *Turritella rivurbana*, which came from the Yazoo clay member on Town Creek, all are from the Moodys marl, which forms the basal member of the Jackson formation and underlies the Yazoo clay. The illustrations are from photographs made in the laboratory of the U. S. Geological Survey by Mr. W. O. Hazard and retouched by Miss Frances Wieser.

Station 4250. Moodys Branch, Jackson, Miss.: from the first bluff below the first bridge east of the Institution for the Blind. T. W. Vaughan, 1900.

Station 6458. Moodys Branch, Jackson, Miss.; S. W. ¼ sec. 35, T. 6 N., R. 1 E. Wythe Cooke 1912.

Station 6466. Town Creek, Jackson, Miss.; 200 yards south of the intersection of Rankin and South State Streets. Wythe Cooke, 1912.

Terebra jacksonensis Cooke, n. sp. Fig. 1

Shell slender, apical angle about 20°, suture distinct; nucleus containing 3 or 4 smooth, polished, convex whorls; postnuclear whorls 9½ in type, ornamented by even, rounded, slightly sinuous axial ribs which are cut by an impressed spiral line one-third the width of the whorl in front of the suture and which become obsolete at the anterior end of the body whorl. Rounded fasciole bordered posteriorly by a strong cord which terminates abruptly at the inner lip. Altitude 13½ mm.; lat. of body whorl 3½ mm.

Station 4250, Moodys Branch, Jackson, Miss. U. S. N. M. No. 353,937.

This species, which is very abundant in the Moodys marl member at Jackson, somewhat resembles de Gregorio's figure of *T. andrega*, which has a deeper spiral furrow on the whorls.

Drillia dorseyi Cooke, n. sp. Fig. 2

Shell small, robust, apical angle 35° to 40°; nucleus blunt, polished, containing about 3¼ convex whorls, about ¾ mm. long. Postnuclear whorls 4¾ in type, about 2½ times as wide as long; polished, smooth or very faintly threaded back of the suture but distinctly threaded on the anterior half of the body whorl; decorated with 11 or 12 rounded, axial ribs on each whorl.

Deposits of Claiborne and Jackson age in Georgia (jointly with H. K. Shearer): U. S. Geol. Survey Prof. Paper **120**: 41–81. 1918.

Correlation of the deposits of Jackson and Vicksburg ages in Mississippi and Alabama: This JOURNAL **8**: 186–198. 1918.

Correlation of the Eocene formations in Mississippi and Alabama: U. S. Geol. Survey Prof. Paper **140**: 133–136. 1925.

The Cenozoic formations [of Alabama]: Alabama Geol. Survey, Geology of Alabama (in press).

Suture distinct, somewhat flexuous. Canal straight; aperture about two-thirds as long as the body whorl. Outer lip broken. Alt. 5¼ mm.; lat. 2 mm.

Station 4250, Moodys Branch, Jackson, Miss. U. S. N. M. No. 353,938.

Drillia dorseyi is smaller, less slender, and has a somewhat shorter nucleus than *D. tantula* (Conrad) from the Byram marl at Vicksburg. A somewhat larger shell of 5 whorls, measuring 6½ mm. in altitude and 2¼ mm. in latitude, has only 7 ribs on each whorl. It may be a distinct variety.

Pleurotoma julia Cooke, n. sp. Fig. 3

Shell small, fusiform; apical angle about 30°. Nucleus large, smooth, tip broken, 2½ whorls remaining. Postnuclear whorls 4¼ in type, shouldered cancellated; entire whorl covered by regularly spaced and nearly equal spiral threads, 7 threads on the third whorl; many low, rounded, protractive ribs becoming obsolete on the body whorl. Canal straight; aperture wide, three-sevenths as long as the shell; columella smooth; outer lip thin, smooth within. Sinus adjacent to the suture, shallow. Altitude 7 mm.; latitude 2¼ mm.

Station 4250, Moodys Branch, Jackson, Miss. U. S. N. M. No. 353,939.

This pretty little species, of which only one specimen is in the National Museum collection, is given the obsolete name "Pleurotoma" because of the chaotic condition of the nomenclature of the Turritidae.

Cancellaria jacksonica Cooke, n. sp. Fig. 4

Shell large, stout, falsely umbilicated, apical angle about 60°. Nucleus naticoid, of 2 smooth whorls. Postnuclear whorls 5 in type, decorated with many spiral threads; ribs retractive, making an angle of about 25° with the axis, about twice as thick as the threads; 13 moderately large varices on type. Pillar lip with 3 folds; outer lip with 9 denticulations. Altitude 15 mm.; latitude 8½ mm.

Station 4250, Moodys Branch, Jackson, Miss. U. S. N. M. No. 353,940.

Cancellaria jacksonica is very abundant in the Moodys marl member of the Jackson formation at Jackson. It is stouter, more profusely ribbed, and has larger varices and more denticulations than *C. mississippiensis* Conrad, from Vicksburg.

Olivella jacksonensis Cooke, n. sp. Fig. 5

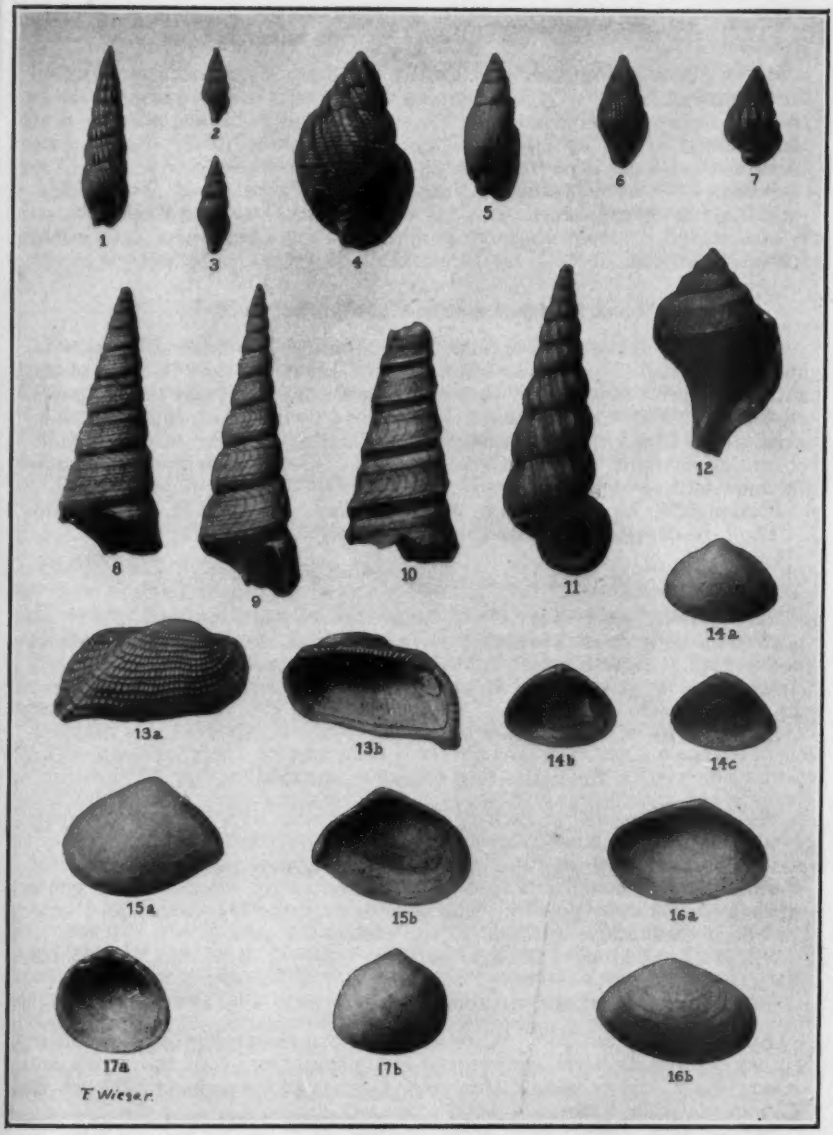
Shell small, spire high, apical angle about 40°. Nucleus spherical, ¾ mm. in diameter. Whorls 4½ or 5, slightly convex, suture deep; no deposit of enamel behind the suture. Altitude 11 mm.; latitude 4 mm.; altitude of outer lip 5½ mm.

Station 4250, Moodys Branch, Jackson, Miss. U. S. N. M. No. 353,941.

This species is very common in the Moodys marl member at Jackson. Most of the shells are a little smaller than the type. *O. jacksonensis* is similar in general aspect to specimens from the Gosport sand at Claiborne, Ala., labelled *Oliva gracilis* Lea, which are somewhat higher-spired and have larger nuclei. The suture is like that of *O. mississippiensis* Conrad from the Byram marl at Vicksburg, but *O. mississippiensis* is much higher-spired and its nucleus is much larger

Conomitra jacksonensis Cooke, n. sp. Fig. 6

Shell fusiform, stout, apical angle about 45°. Nucleus small, globular, smooth. Postnuclear whorls 5¼, cancellated, turrited; entire whorl except



Figs. 1–17.—Fig. 12 natural size; all others × 2.

1—*Terebra jacksonensis;* 2—*Drillia dorseyi;* 3—*Pleurotoma julia;* 4—*Cancellaria jacksonica;* 5—*Olivella jacksonensis;* 6—*Conomitra jacksonensis;* 7—*Alectrion jacksonensis;* 8—*Turritella jacksonensis;* 9—*Turritella lowei;* 10—*Turritella rivurbana;* 11—*Epitonium cribrum;* 12—*Levifusus moodianus;* 13—*Barbatia jacksonensis;* 14—*Spisula jacksonensis;* 15—*Tellina vicksburgensis* var. *moodiana;* 16—*Tellina vaughani;* 17—*Cardium gardnerae.*

a narrow band in front of the suture covered with fine, impressed, spiral lines; axial sculpture of close, rounded riblets with interspaces as wide as the ribs, tending to form beads on the sutural band, becoming obsolete near the aperture. Inner lip with 4 strong, straight, parallel folds; outer lip with 14 threads within. Altitude 8½ mm.; latitude 4 mm.

Station 4250, Moodys Branch, Jackson, Miss. U. S. N. M. No. 353,942.

This species greatly resembles *Conomitra fusoides* (Lea), but its protoconch is smaller and its sculpture more uniform and more persistent than in the species from Claiborne.

Alectrion jacksonensis Cooke, n. sp. Fig. 7

Shell small, robust, apical angle 50°. Nucleus small, smooth, globular, about 3 whorls. Postnuclear whorls 5, with a narrow band in front of the suture cut into beads by the ribs; area between the band and the periphery crossed by about 4 spiral striae; base of body whorl with spiral threads; axial riblets high, narrow. Outer lip thick, with 6 strong threads within; columella straight, short, with 5 short folds. Canal outcurved. Altitude 7½ mm., latitude 4 mm.

Station 4250, Moodys Branch, Jackson, Miss. U. S. N. M. No. 353,943.

The type of *Alectrion jacksonensis* is unique.

Turritella jacksonensis Cooke, n. sp. Fig. 8

Shell rapidly expanding; apical angle 25°. Suture impressed. Whorls postero-medially constricted, twice as broad as high, ornamented with faintly nodular spiral threads which continue over the base. Growth lines deeply sinuated on the constriction and gently flexed on the periphery. Altitude 20 mm.; latitude 7 mm.

Station 4250, Moodys Branch, Jackson, Miss. U. S. N. M. No. 353,944.

Turritella lowei Cooke, n. sp. Fig. 9

Shell slender, apical angle 20°, becoming stouter with increasing growth. First 8 or 10 whorls nearly cylindrical or slightly constricted; later whorls flat. Suture deeply depressed; growth lines sigmoid. Sculpture of faint, spiral threads becoming more conspicuous on larger whorls; many young shells appear almost smooth. One or two whorls broken from tip of type; 12 whorls remaining. Altitude 23 mm.; latitude 8 mm.

Station 4250, Moodys Branch, Jackson, Miss. U. S. N. M. No. 353,945.

Turritella rivurbana Cooke, n. sp. Fig. 10

Apical angle about 20°. Whorls carinated, slightly constricted medially, suture depressed; spiral sculpture of one strong thread on the carina and several finer, widely spaced threads. Altitude of a fragment of 5 whorls 17 mm.; latitude 8 mm.

Station 6466, Town Creek, Jackson, Miss., U. S. N. M. No. 353,946.

In form, this species resembles *T. carinata* Lea from Claiborne, but lacks the crowded, microscopic, spiral threads, its suture is more depressed, and it differs also in the direction of its growth lines. In front of the carina the growth lines of *T. rivurbana* are strongly protractive (bent clockwise to the axis), making an obtuse angle with the lines behind the carina, but in *T. carinata* they are retractive and make an acute angle.

Epitonium cribrum Cooke, n. sp. Fig. 11

Subulate, apical angle about 25°. Nucleus small, of at least 4 smooth convex whorls (broken in type); 10 succeeding whorls moderately convex. Entire surface (including base and varices) covered by fine, close-set, reticulating threads which produce a punctate or sievelike appearance under the microscope. Axial sculpture of low, rounded, retractive ribs which become fainter on the larger whorls; strong, round, cordlike varices on fourth and seventh whorls and at the aperture; base with one strong cord. Altitude 23 mm.; latitude 8 mm.

Station 4250, Moodys Branch, Jackson, Miss. U. S. N. M. No. 353,947.

Levifusus moodianus Cooke, n. sp. Fig. 12

Shell stout, apical angle 75°. Nucleus smooth, whorls rounded (tip broken). Postnuclear whorls 5½, rounded, becoming faintly shouldered, covered with close spiral threads except a bare band on the anterior part of the body whorl. Canal long, straight (tip broken). Inner lip with two low broad folds. Outer lip thin, smooth within (broken). Altitude 31½ mm.; latitude 20 mm.

Station 6458, Moodys Branch, Jackson, Miss. U. S. N. M. No. 353,948.

Barbatia jacksonensis Cooke, n. sp. Fig. 13a–b

Shell small, inflated, trapezoidal; beaks at the anterior fourth; with a more or less well defined depression extending from the umbones to the ventral margin; sharply angulated on the posterior slope; posterior border acutely angulated with the base; exterior surface strongly ribbed, the ribs somewhat farther apart on the posterior slope than elsewhere, strongly imbricated in harmony with the lines of growth. Longitude 13 mm.; altitude 8 mm.; semidiameter 3 mm.

Station 6458, Moodys Branch, Jackson, Miss. U. S. N. M. No. 353,949.

This species is much smaller than *B. cuculloides*, from the young of which it differs in its greater inflation, stronger ribs, and much coarser and more even imbrication, which imparts to *B. jacksonensis* a cancellated appearance like a tile roof.

Spisula jacksonensis Cooke, n. sp. Fig. 14a–c

Shell small, subovate, moderately inflated; beaks central, adjacent; surface smooth except the dorsal areas, which are wrinkled; anterior dorsal area slightly depressed; base arcuate; pallial sinus little longer than wide, rounded in front; hinge with strong ventral lateral laminae, adjacent sides of laminae striated; arms of cardinal tooth of left valve forming a right angle. Longitude 8.2 mm.; altitude 6.2 mm.; semidiameter 2 mm.

Station 6458, Moodys Branch, Jackson, Miss. U. S. N. M. No. 353,950.

The type of *Spisula jacksonensis* is a left valve. This very abundant species differs from *S. funerata* (Conrad) from Vicksburg in its central beaks, more rounded base and shoulders, and in the symmetrical position and rectangular shape of its left cardinal tooth, which in *S. funerata* is twisted forward and forms an acute angle.

Tellina vicksburgensis var. **moodiana** Cooke, n. var. Fig. 15a-b

The variety at Jackson differs from the typical form at Vicksburg in its

larger size, proportionately greater altitude, and slightly stronger sculpture. Longitude 11½ mm.; altitude 8 mm. semidiameter 2½ mm.

Station 4250, Moodys Branch, Jackson Miss. U. S. N. M. No. 353,951.

Tellina vaughani Cooke, n. sp. Fig. 16a–b

Shell subelliptical, beaks slightly anterior, moderately inflated; anterior end somewhat more acute than the posterior; surface covered with close, flat, concentric threads which are fewer, narrower, and farther apart on the dorsal slopes. Longitude 11½ mm.; altitude 8 mm.; semidiameter 3 mm.

Station 4250, Moodys Branch, Jackson, Miss. U. S. N. M. No. 353,952.

Cardium (Laevicardium) gardnerae Cooke, n. sp. Fig. 17a–b

Shell small, rather thick, subcircular; entire surface smooth and polished, with faint radial markings; faintly ribbed within; worn shells more or less cancellated, with concentric ridges or wrinkles predominating; original color apparently purple. Longitude 8½ mm.; altitude 8 mm.; semidiameter 2½ mm.

Station 4250, Moodys Branch, Jackson, Miss. U. S. N. M. No. 353,953.

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ANTHROPOLOGICAL SOCIETY

591ST MEETING

The 591st meeting was held in the New National Museum October 20, 1925. Dr. JOHN M. COOPER read a paper on *The Têtes de Boule of the upper St. Maurice*, basing his remarks on two visits to them, one in 1916, the other in June, 1925. They are a hunting and trapping people who occupy most of the watershed of the St. Maurice River in Quebec, the northern band straddling at points the Hudson Bay divide. Some of the anthropometrical averages obtained for adult men were: stature, 168.6; cephalic index, 80.67; face breadth, 147.4. The linguistic material gathered seems to show quite clearly that the language spoken is a Cree dialect. The Têtes de Boule thus appear as the easternmost Cree. The chief phonetic change is Tête de Boule *r* for common Cree *y*. The northern band of the Têtes de Boule call themselves Obidjiwan iriniwäk, "men of Obidjiwan." They have the typical northeastern family hunting grounds, with inheritance usually in the male line and with use of selection and rotation for conserving the game supply. Marriage is usually patrilocal. Women are well treated. No trace of sib organization or of totemic tendencies was found. The chief has very limited power. There are two assistant chiefs. The chieftaincy is not necessarily hereditary, but actually tends to pass from father to son. Among the adolescent boys and girls, chums are common, but no indication of the gang appeared. Baskets are decorated with spruce root, but the double-curve motive, quill and moose hair ornamentation, and bark etching are absent. Psychically the Têtes de Boule are characterized by evenness of temper, good humor, truthfulness and honesty, and socially by marked peacefulness and democratic spirit. The social atmosphere and organization is distinctly non-competitive, even competitive play being seemingly absent.

592D MEETING

The 592d meeting was held in the National Museum, November 17, 1925. Dr. ALEŠ HRDLIČKA addressed a crowded hall on *Ancient man in the far east*. He had just returned from a trip around the world made to study at first hand some of the crucial evidence on primitive man of the past and present. He dealt more particularly with the Rhodesian skull. As a result of his research and observation at the Broken Hill mine, he has been able to clear up many of the uncertainties that have surrounded the discovery of this remarkable specimen. It was found by a miner near the lower end of an old bone- and detritus-filled cave that sloped down from the former surface. The upper part of the cave was largely filled with a great quantity of animal bones, among them a few human remains, and some stone artefacts. The long bones, including the human ones, had been broken or split to extract the marrow. Beyond this part of the cave was a stratum, thirty feet thick, of laminated soft lead ore, separating the anterior from the lower posterior section of the cave. The skull of Rhodesian man was found in the lower section, at a depth of 60 feet from the surface. It was not associated with other bones, but not far from it was found a human tibia and a fossil skull of a lion. The bones brought with the skull to England, aside from the tibia, may not belong to the lower part of the cave. These remains are from both male and female skeletons, show varying alteration, and clearly do not belong with the skull. The skull itself was found resting upright and intact, without the lower jaw, in a pocket of detritus and "bat" bones, as if put there intentionally. It showed originally no scratches or damage. Below it was found what looked to the discoverers like a roll of mineralized thick hide, and still lower and at some distance the human tibia and lion's skull. The last has apparently disappeared since the discovery. The roll may have been laminated lead ore. It was smelted, as was the mass of mineralized bones from the outer part of the cave. How the skull came to be in such a place at the base of the cave, and who may have put it there, are questions which may never be answered. Nor is it possible at present definitely to classify Rhodesian man among any of the human races of the past or present. The find will probably remain a great anthropological enigma until further evidence bearing on this form of man be discovered.

593D MEETING

The 593d meeting was held on December 15, 1925. Mr. W. H. JACKSON, photographer (1870–79) to the Hayden Geological Surveys, related his *Experiences with the Pawnee Indians 50 years ago*, his address being illustrated with slides from his negatives made in 1868–71. Mr. JACKSON crossed the plains to California in 1866, the last year of overland travel by wagon train. Returning eastward as far as Omaha, he went into the business of photography, making pictures of the Indians, frequent visitors to the city, and of their outlying villages, with occasional trips to take views along the completed portions of the Union Pacific Railroad. The Pawnee Reservation, where most of the pictures were made, was on the Loup Fork of the Platte River, about 100 miles west of Omaha. The two principal villages, composed entirely of earthen lodges 30 to 60 feet in diameter, at the eastern end of the reservation, were the ones most frequently visited. Lieut. Long, who had passed that way 50 years previously, had estimated the Pawnee there to number 10,000 or more, but disease and constant warfare with the neighbor-

ing Sioux, had reduced them to less than one-fourth of this number. Further aggressions, intensified because of the enlistment of many Pawnees in the army to assist in protecting overland travel, led finally to their removal to the Indian Territory and the entire abandonment of their villages by 1875. Besides detailed views of the villages, typical portraits, and the Industrial School with groups of children, "before and after" illustrations were shown in conclusion of the laborious and complicated "wet plate" process for making photographs 50 years ago.

JOHN M. COOPER, *Secretary.*

SCIENTIFIC NOTES AND NEWS

Dr. R. B. SOSMAN of the Geophysical Laboratory, Carnegie Institution of Washington, is giving a continuation of a course of lectures on "Geophysics," begun at the Massachusetts Institute of Technology last year. The general subject of the present series is *Elastic waves and the Earth's structure.*

The Ore Deposits Club met at the Geological Survey on February 19, to discuss the subject of *Zoning of ore deposits.*

The Pick and Hammer Club met at the Geological Survey on February 20. Program: KIRK BRYAN: *Application of geology to archaeology;* T. S. LOVERING: *Organic precipitation of copper.*

Corrigenda.—The following corrections are to be made in the preceding issue of the JOURNAL: p. 88, 14th line from bottom, for "tendon" read "tenon" and for "nearly" read "neatly"; p. 88, 12th line from bottom, the parenthesis should close with "long" and a comma should follow "branch"; p. 91, 9th and 10th lines, read "it appeared that, after becoming loaded with the molecules, they could not pass" instead of "it appeared that the molecules were so crowded that they could not pass"; p. 91, 22d line, strike out "which"; p. 91, 9th line from bottom, read "may" instead of "could".